Coupled Mode Problems for Bottom Interacting Sound
and
Coupled Mode Problems for Bottom Interacting Sound: Student Support (Assert)

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LONG-TERM GOAL

The long-term goal of this research is to improve our ability to model and predict VLF acoustic propagation in shallow water with particular emphasis on the range dependence of the medium and the geoacoustic properties of the bottom, and to quantify the various factors affecting the overall acoustic energy budget in shallow water propagation.

OBJECTIVES

Our scientific objectives are to incorporate the effects of sediment anisotropy, strong sediment attenuation, and the effects of both deterministic and stochastic medium properties into a local coupled mode propagation model, and to develop accurate theory and robust numerical algorithms for the shallow water propagation problem.

APPROACH

We are using an approach based on coupled local modes to carry out a systematic study of the effects of scattering, normal dispersion, anisotropy and intrinsic attenuation on a propagating shallow water acoustic signal with strong bottom interaction. The coupled mode theory is developed from the first order equations of motion for the stress and displacement rather than from the second order equations for a velocity or displacement potential. The later approach introduces coupling coefficients depending on the second-order derivatives with respect to the range coordinate of the local mode functions. These second-order coupling coefficients are an artifact of the formulation, and not present in the coupled mode theory based on the first order equations of motion.

WORK COMPLETED

We have derived the proper low p (slowness) mixed boundary condition for the spectral diffusion equation of Odom and Mercer (1996). We have incorporated a very general elastic mode code into our mode coupling program. The elastic mode code (Park, 1996) is capable of computing the elastic (seismo-acoustic) modes of a layered medium comprising anisotropic layers with hexagonal symmetry and arbitrary symmetry axis orientation. Two papers were completed and submitted to refereed journals (Park and Odom, 1998; Park and Odom, in press 1999).

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RESULTS

Derivation of the low *p* mixed boundary condition for the spectral diffusion equation requires the use of improper modes representation of the elastic continuum. We employed the formulation of Maupin (1996), and have found that frequency dependent function multiplying the spectral energy flux varies as (1/frequency). This provides the proper total loss limit as frequency increases, and also indicates that the approximate boundary condition assuming total loss is likely to be a poor approximation at even moderate frequencies.

Transverse isotropy (TI), which by definition has hexagonal symmetry and a vertical symmetry axis, is an almost ubiquitous feature of marine sediments. There is, however, no reason to expect that the symmetry axis remains vertical in regions with non-planar bottom topography. Bottom topography will cause the symmetry axis to rotate, and when this occurs, bottom interacting modes can develop significant quasi-SH (quasi-Love) particle motion components. Figure 1 is a plot of phase velocity vs. symmetry axis angle. Notice that for symmetry axis tilt of zero degrees (TI), the phase velocities of the quasi-SH (labeled qL) and the quasi-P-SV (labeled qR), are distinct and well separated. But that as the symmetry axis rotates, the qL and qR phase velocities can approach very closely. This has a dramatic effect on the mode coupling in a range dependent medium. Figure 2 is the coupling matrix for a symmetry axis tilt angle of 30 degrees. Whereas the mode coupling matrix for a range dependent isotropic or TI medium is strongly diagonally dominant indicating mostly nearest-neighbor interaction (Odom et al., 1996), the mode coupling matrix shown in Figure 2 has large terms far from the diagonal. This indicates coupling to SH in the bottom, and indicates that coupling to SH may be an important loss mechanism in regions of strong bottom anisotropy. The frequency in the example is 15 Hz.

IMPACT/APPLICATIONS

The development of additional code for more general anisotropic bottom structures and the derivation of the proper boundary condition for the spectral diffusion equation indicate steady progress towards meeting our scientific objectives. This research is directly applicable to predicting the effect of a complicated shallow water environment on the acoustic field.

TRANSITIONS

Modal methods for modeling in random range dependent shallow water waveguides should provide important constraints on the most significant waveguide properties affecting propagation at low frequencies.

RELATED PROJECTS

Our research is directly related to other programs studying surface, volume and bottom interaction effects, including 6.2 and 6.3 efforts to quantify bottom backscatter and bottom loss effects in littoral regions.

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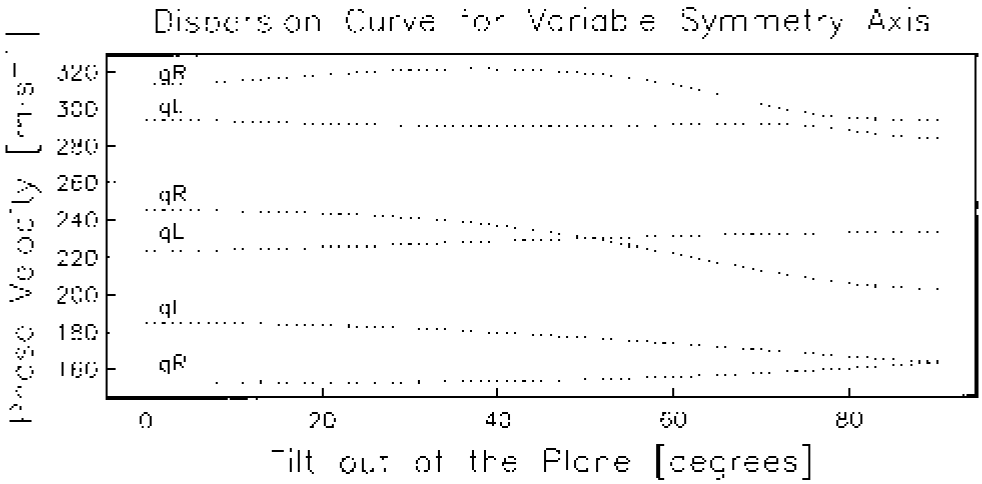

Figure 1. Modal phase velocities for a layered anisotropic hexagonally symmetric sediment model as a function of symmetry axis tilt angle. Note that the quasi-SH modes (qL) and quasi-P-SV (qR) modes attract and repel as the symmetry axis is rotated.

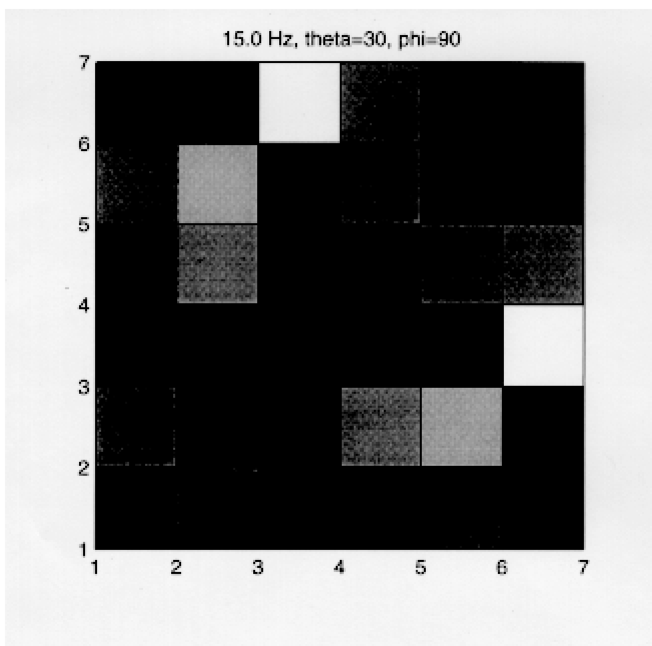

Figure 2. Mode-mode coupling matrix for the same sediment model as in Figure 1 with a symmetry axis tilt of 30 degrees. The mode coupling exhibits significant non-nearest neighbor interactions among the modesi due to coupling between qL and qR modes. This is in contrast to the heterogeneity induced mode coupling in isotropic and transversely isotropic media in which the coupling is nearest neighbor dominant.